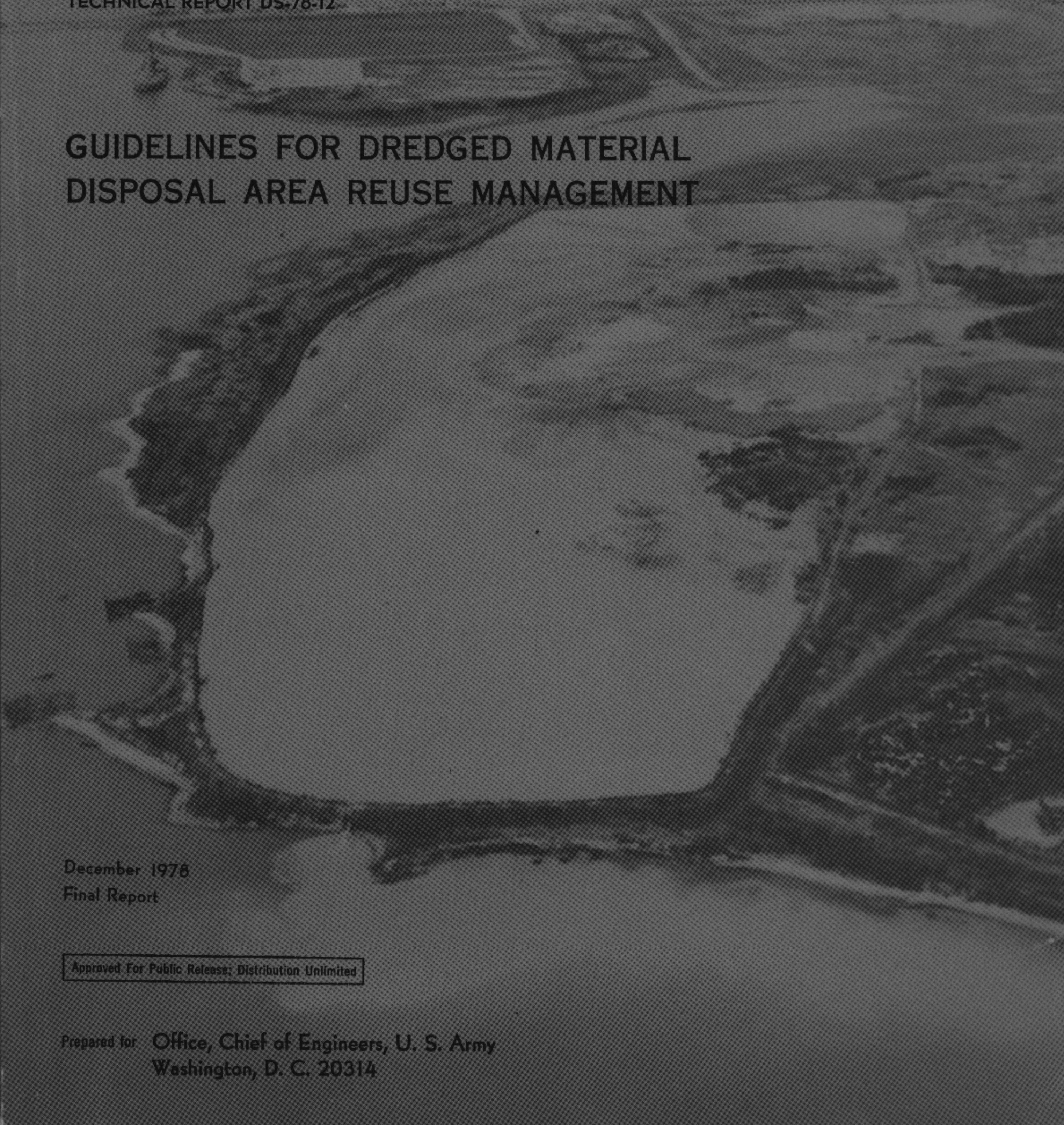
SYNTHESIS OF RESEARCH RESULTS

DREDGED MATERIAL RESEARCH PROGRAM

U.S. ARMY ENGINEER WATERWAYS EXPERIMENT STATION

TECHNICAL REPORT DS-78-12



GUIDELINES FOR DREDGED MATERIAL DISPOSAL AREA REUSE MANAGEMENT

December 1978
Final Report

Approved For Public Release; Distribution Unlimited

Prepared for Office, Chief of Engineers, U. S. Army
Washington, D. C. 20314

THE DMRP SYNTHESIS REPORT SERIES

Technical Report No.	Title
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DS-78-2	Processes Affecting the Fate of Dredged Material
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The purpose of this report is to present disposal area reuse management guidelines developed under the Dredged Material Research Program (DMRP). The guidance provided herein has a threefold purpose. First, it is intended to describe the concept of disposal area reuse and to show the role of disposal area reuse in the long-range planning of dredged material disposal. Second, it provides guidance for determining the feasibility of developing reusable disposal areas, either new areas or existing areas converted for reuse. Third,

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20. ABSTRACT (Continued).

it presents general guidance for preparing designs for reusable disposal areas.

One of the most difficult problems facing the Corps is the acquisition of land for dredged material disposal areas. Choice land areas located near dredging projects have already been used, either for dredged material disposal or for commercial development. Undeveloped lands near dredging projects are frequently "wetlands," whose necessity in biological cycles make them too valuable to be used for dredged material disposal activities. A solution to this problem is to extend the service life of disposal areas as much as possible through the implementation of disposal area reuse management (DARM) practices.

General guidance is provided for planning and site selection, reuse of existing disposal areas, and the development of disposal area reuse management facilities (DARM). The guidance includes the identification of pertinent legal, environmental, and technological factors which influence the planning and selection of reusable sites.

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PREFACE

This report synthesizes results of the Dredged Material Research Program (DMRP) pertinent to extending the service life of disposal areas by use of disposal area reuse management practices. The study was conducted as Work Unit 5C12 of the DMRP for the Office, Chief of Engineers, at the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi. This work unit is part of Task 5C, Disposal Area Reuse (Dr. Raymond L. Montgomery, Manager) of the Disposal Operations Project (Mr. Charles C. Calhoun, Jr., Manager).

The study was conducted by the Environmental Engineering Division (EED) of the Environmental Laboratory (EL), WES, under the general supervision of Dr. John Harrison, Chief, EL, Dr. Roger T. Saucier, Special Assistant, EL, and Mr. A. J. Green, Chief, EED.

This report was written by Dr. Raymond L. Montgomery, Chief, Water Resources Engineering Group, EED, Mr. Alfred W. Ford, EED, Ms. Marian E. Poindexter, EED, and Mr. Michael J. Bartos, formerly of EED. This report is also being published as Engineer Manual 1110-2-5010.

The Commander and Director of WES during the study was COL John L. Cannon, CE. Technical Director was Mr. F. R. Brown.

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CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI)
UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
acres	4046.856	square metres
cubic yards	0.7645549	cubic metres
feet	0.3048	metres
inches	25.4	millimetres
miles (U. S. statute)	1.609344	kilometres
pounds (mass)	0.4535924	kilograms
square feet	0.09290304	square metres

GUIDELINES FOR DISPOSAL AREA REUSE

PART I: INTRODUCTION

Background

1. The Dredged Material Research Program (DMRP) included research to develop a wide variety of approaches to the improvement of Corps of Engineers (CE) dredged material disposal practices. One of the most difficult problems facing the CE is the acquisition of land for dredged material disposal areas. Choice land areas located near dredging projects have already been used, either for dredged material disposal or for commercial development. Undeveloped lands near dredging projects are frequently "wetlands," whose necessity in biological cycles make them too valuable to be damaged or destroyed by dredged material disposal activities. A solution to this problem is to extend the service life of disposal areas as much as possible through implementation of disposal area reuse management practices. The objectives of disposal area reuse management (DARM) practices are simply to develop procedures for maintaining disposal areas convenient to dredging operations for an infinite period while ensuring that disposal operations remain environmentally acceptable and operational.

2. The purpose of this report is to present disposal area reuse management guidelines developed under the DMRP. The guidance provided herein has a threefold purpose. First, it is intended to describe the concept of disposal area reuse and to show the role of disposal area reuse in the long-range planning of dredged material disposal. Second, it provides guidance for determining the feasibility of developing reusable disposal areas, either new areas or existing areas converted for reuse. Third, it presents general guidance for preparing designs for reusable disposal areas.

Concept of Disposal Area Reuse

3. A reusable disposal area is one from which all or part of the dredged material is removed to restore storage capacity to the area. In this sense, a reusable disposal area can be regarded as a dredged material transfer station, where dredged material is collected, processed if necessary, and removed for productive use or inland disposal. The advantages of a totally reusable disposal area (one from which all dredged material is removed) over a conventional area are:

a. Elimination of land acquisition requirements, except for inland disposal.

b. Justification for increased costs for high-quality disposal area design and construction.

c. Permanent availability of disposal areas near dredging sites.

d. Availability of dredged material for use as landfill or construction material.

Partially reusable disposal areas, those from which only part of the dredged material is removed, have the same advantages, but only during the service life of the disposal area. For example, the practice of removing dredged material from within a disposal area for use in dike raising is a form of disposal area reuse because the service life of the disposal area is extended by the removal of some of the dredged material.

4. In addition to acting as a dredged material transfer station, a reusable disposal area will also be a dredged material processing center. The functions of a reusable disposal area may include coarse material separation and processing to provide a specified coarse-grained product; dewatering to make fine-grained dredged material suitable for productive use, to make it easier to transport, or to increase the solids storage capacity of an inland disposal site; and treatment of contaminated dredged material prior to removal.

5. Dredged material can be removed from a disposal area for a variety of reasons, which fall into one of two categories: productive use and/or inland disposal. Productive uses that have been investigated

during the DMRP include use for habitat creation and land improvement. The removal of dewatered dredged material from disposal areas for use in marsh creation provides some advantages over pumping dredged slurry directly to the marsh site (bypassing the disposal area). Using the dewatered dredged material ensures greater strength, provides better control of surface elevation, and eliminates the need for a confinement structure. Concepts for land improvement using dredged material include strip mine reclamation, uses in solid waste management (sanitary landfill cover, etc.), and use as an agricultural soil or soil amendment.[1] Field demonstrations to evaluate concepts for using dredged material for habitat creation and strip mine reclamation were initiated under the DMRP.

6. In some cases it may be feasible or necessary to remove dredged material from a disposal area and transport it to an inland disposal site to ensure that the disposal area is reusable. Such an operation could be the solution for a problem of land acquisition near the dredging site. The transportation, productive use, and inland disposal of dredged material are the subject of recently completed DMRP research and will be summarized in Part II of this report.

7. It is impractical to incorporate within this report all the detailed information from the research studies that provide important input into the development of reusable sites. In some cases, large portions of a research report would have had to be included to present the ways behind the guidance provided. Therefore, this report is structured to present the "how to do it" guidance for the development of disposal area reuse sites. In doing this, the report identifies available planning, design, construction, and management guidance in the form of technical reports, engineering manuals, and DMRP synthesis reports.

Need for Policy Changes

8. Present philosophy and policy regarding dredged material disposal is sometimes in conflict with the most efficient use of available disposal area resources. Legal and policy constraints regarding sale and use of dredged material, removal of dredged material from disposal

areas, and ownership of dredged material were identified by DMRP research.[2]

9. A greater degree of flexibility regarding removal of dredged material and sales or donations of material is evident in cases of Federal ownership of disposal areas. In both the Philadelphia and Sacramento Districts, where larger scale DARM programs were developed, sites are Federally owned. When disposal areas are owned by project sponsors, usually local or State agencies, questions arise as to legal jurisdiction and ownership of dredged material placed in the sites. The issue becomes more complex when easements are secured on private lands by State or local sponsors for disposal by Federal authority. The DMRP has completed research identifying major legal and policy constraints in this area.[3]

10. In instances when easements are secured on private lands or lands are provided directly by local sponsors, acquisition of the site is granted on conditions relating to ultimate return of the site to the private owner or local sponsor. Return is usually tied to an expiration date for easement or achievement of a maximum fill elevation within the disposal area. Opposition by owners or sponsors to removal of dredged material from such sites is understandable since higher elevations gained by disposal operations may greatly increase land values and potential for future development. Disposal areas acquired with eventual return to owner or sponsor are suited to DARM concepts involving onsite landfill or perimeter mounding. Such operations would usually add greater value to the lands by providing suitable foundation conditions for heavier construction and greater aesthetic benefits upon return of the site for subsequent development.

11. Expansion of present sales and donation programs is hindered by constraints imposed by both Federal law and Corps policy. Sale of dredged material from disposal areas is usually through a competitive bidding process, considering the material as excess government property. Similar procedures, governed by State law or local ordinance, are used in sales through the project sponsors. These procedures are effective for large quantities when the market is present, reflected by high demand.

However, the procedure is not well suited to sale of smaller quantities or when quick access to the material is required by the user. In such cases direct negotiation between the user and project sponsor would be more appropriate and would encourage more frequent sales of material.

12. When material is sold as excess government property from Federally owned sites, revenue is received by the General Services Administration (GSA). Diversion of these funds to the District O&M budget would encourage increased promotion of such programs and would allow greater use of resources for management of disposal operations. On the other hand, if funds from sales were diverted to the Districts, problems with timing may arise. Present requirements to expend all available funds within a fiscal year may prevent the most judicious use of the funds. Resolution of these problems would require an exception to or the reform of present overall funding policies.

PART II: PLANNING AND SITE SELECTION

13. A disposal area reuse project requires total project planning and careful site selection. The major objective in planning a reusable site is to provide long-term dredged material disposal capacity near the dredging project. The resource dredged material is matched with needs of this resource material for productive uses. The general planning and site selection process is outlined with detailed guidance.

Constraints Associated with Disposal Area Reuse

14. In the development of a reusable disposal area, the dredged material must either be used productively and/or disposed of at inland sites. There are a number of constraints associated with these. They can, however, be overcome with proper planning and coordination. Legal constraints that limit the range of possible uses of dredged material, the laws and regulations that control its sale or donation, and the official and public attitudes that can affect such actions were investigated. Other constraints are related to social, environmental, and institutional matters.

15. When disposal area reuse is considered, questions arise as to legal jurisdiction and ownership of dredged material placed in disposal areas owned by project sponsors and who should benefit from the productive uses of the dredged material. At this time there are no clear solutions to the problem of disposal area ownership. However, it appears from the DMRP research that for the most efficient use of available disposal area resources, more consideration should be given to Federal control of disposal areas. For the purpose of this report, "Federal control" is defined as either Federal ownership or long-term agreements with land owners to use the disposal site.

Productive uses considerations

16. The first step in planning for disposal area reuse through productive uses of dredged material is to determine ownership of the dredged material. From the DMRP research it was concluded that

ownership, in terms of right or freedom to remove and use the material productively, is distributed as follows. However, these are general cases and ownership is highly variable from state to state.

Location of Material	Ownership
In place on bottom of navigable streams and lakes and on coastal shelf within limits of the territorial sea.	The State owns the material in its natural state.
Placed by dredge on shoals or on water bottom.	Ownership does not change.
Upland sites owned in fees by State or local interest (harbor commission, levee board).	Dredged material belongs to entity owning the land.
Upland sites for which an easement or permit was obtained by local interests.	Material belongs to the owner of the fee, unless there was prior agreement that the material could be removed.
On land for which the Federal Government holds a grant or proscriptive easement.	Question could turn on intent of Government when materials were placed on land. If material is stacked and it is the stated intent of the Government to move it at a later time, it then belongs to the Government. If it is spread over the land with no apparent intent to move it, it would then belong to the owner of servient estate.
On private land for which a permit or license was granted by the owner to the Corps.	The _quid pro quo_ was the value to be added to the land by the dredged material, and the owner would claim it. It may or may not be subject to payment of a royalty to the State.
On private land for which license is bought and paid for by Corps or a dredging contractor with expectation of later removing the materials.	Material belongs to the holder of such a license and the material may be subject to a State royalty if it is placed in commerce.

(Continued)

Location of Material	Ownership
Placed on Federal lands such as a military base or land owned by another Federal agency.	Material belongs to Federal Government and may be disposed of with the land as realty or, if stacked in piles for later removal, as personalty.
Placed on fastland created by disposal of dredged material over a period of years (e.g., Craney Island, Norfolk, Va., and Sand Island, Honolulu) and occupied by the Federal Government.	Material on the island would appear to be property of the Federal Government.
Placed on shoals which break surface to create fastland (e.g., bird sanctuaries) with the knowledge and approval of State, placed in a water's edge, diked disposal site.	Ownership may depend on all circumstances of the case. If a bird sanctuary or a recreational island was planned as part of a new project, the practice has been to recognize it as State land.

Inland disposal

17. If dredged material cannot be used for productive purposes, the alternative is to transport it inland for disposal. The constraints associated with this alternative are related to costs, environmental factors, and public attitudes.

18. Costs. Costs for moving unusable dredged material inland to disposal sites can be estimated on the basis of the section on dredged material transportation. Detailed cost evaluations should be made during the planning stage based on a project-by-project determination. The determination as to whether cost is a constraint would also be based on the project needs.

19. Environmental factors. Transport of contaminated dredged material inland can affect the environment along the transportation route, at the site, and in adjacent areas.[4] The planners must provide for control measures for mitigating any environmental pollution caused from inland disposal activities. Significant environmental factors from inland disposal activities include the following:

a. Blown dust from transporting equipment (open trucks, rail cars, etc.).

b. Increased traffic congestion where trucks are used.

c. Spills from trucks carrying wet dredged material causing muddy roads.

d. Leachate from disposal area.

e. Vectors.

f. Visual impact and aesthetics.

g. Introduction of foreign plant and animal species and other contaminants into the area.

20. Public attitudes. The public will generally resist plans to locate any type of land disposal facility near their homes. Planners must be aware of the public's negative attitudes toward land disposal facilities, recognize the need to plan an active role in gaining public acceptance, and take a positive attitude toward inland disposal area development.[4] An inland disposal site for contaminated as well as non-contaminated dredged material can be an environmentally sound disposal operation if planned, designed, and operated properly. It should be stressed to the public that major efforts are planned to minimize any adverse effects on local residents. It is important that the planner obtain a gauge of citizen's attitudes concerning the planned inland disposal site early in the planning phase of the project. Knowledge of potential areas of and reasons for opposition, determined through a public attitude survey, will aid the planners in developing a dredged material disposal site which will meet with public approval. Refer to SCS Engineers[4] for more detailed information.

Evaluation of Dredging Activities

21. The necessary data needed by the planner concerning dredging activities were investigated by the DMRP.[5] The following was taken and modified from this research. The steps in obtaining the data needed to make fundamental decisions in planning a reusable site are as follows:

a. Analyze dredging program.

b. Analyze dredging locations and quantities; project to future.

c. Determine dredged material characteristics and possible products.

d. Analyze dredging equipment.

e. Summarize dredging information.

Dredging program

22. A forecast of the dredging program throughout the entire planning period (20, 50, 100 yr, etc.) must be made. The locations, volumes, frequencies, and types of material to be dredged must be estimated. The number, types, and sizes of dredges to be employed should also be scheduled in advance. This information is important for defining project objectives and provides part of the basis for disposal area planning and design.

Dredging locations and quantities

23. Dredging locations and quantities are two of the most important considerations in developing reusable disposal sites. The locations of future maintenance and new work dredging operations should be identified and plotted on a map. This map can then be used in the initial phase of the site selection process. The map will also be useful for delineating the area for conducting a dredged material market study. Locations to be dredged in the future are estimated on the basis of past experience. It is important to estimate the quantity of material to be dredged because the design of the size and number of disposal areas is based on the volume to be dredged. Volume must be known on an annual basis and is also used to estimate the rate at which marketable dredged material products can be made available. A confident estimate of volumes to be dredged as a function of time throughout the planning period is difficult to obtain because shoaling is subject to fluctuations in local hydrology, which cannot be predicted.

Properties of sediments to be dredged

24. Perhaps the most important and difficult estimate is that of the properties of the material to be dredged throughout the design life of the disposal area. Since the feasibility of a reusable disposal area is dictated by the ability of the District to find markets for the dredged material, knowledge of the types of material that will be available is critical. In addition, the design of the area must be based

upon the type(s) of material to be handled.

25. It is necessary at this point in the planning only to determine the approximate amounts and locations of coarse- and fine-grained dredged material expected. Further characterization of the types of material to be dredged, e.g., classification under the Unified Soil Classification System (USCS), is desirable, but not necessary. A simple coarse or fine analysis to be used as an estimate of the availability of high market potential sand and gravel is sufficient. Other properties, e.g., settling characteristics, evaporation/drainage rates, etc., will be necessary for the design methodology presented in Parts III and IV.

26. Table 1 presents the ranges of classification test data determined for dredged material from 400 samples obtained throughout the United States.[6] This table shows that soils ranging from sands to fine clay and organic particles are represented among the materials dredged. Figure 1 shows the types of dredged material found in various regions of the United States. This figure is intended to be only an indicator of the types of material found in the various regions and not a quantitative representation.

Dredging equipment

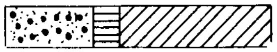
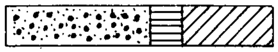
27. In cases where dredging is performed by the CE, the type of equipment can be predicted with some degree of accuracy. However, when dredging is performed under contract, the contractors are free to use equipment of their own choice. It is conceivable that a different type or size dredge would be used each year. Changes in dredge type can have significant effect on the design of a reusable facility because settling basins, whose function is to ensure that water quality standards are met, will be designed for a certain flow and solids concentration. They should be designed on the basis of the maximum size dredge expected to be used on the dredging project.

Summary of dredging information

28. All the required information concerning the locations, sizes, and types of material in a dredging project can be presented on a plan and profile map. The location of the shoal can be shown by the location of the bar in profile and by a shading on the plan. Different shading

Table 1

Ranges of Classification Test Data Determined for Dredged Material*[6]

Region	Total No. Samples	Type Material**	Grain Size† D_{10}, mm	D_{60}, mm	D_{90}, mm	Percent Passing No. 200 Sieve	Atterberg Limits LL	PL	PI	Organic Content, %
A	89		81 <0.001-0.24	89 <0.001-0.42	89 0.0065-0.80	89 1-99 63	66 32-202 104	65 17-71 35	65 9-144 69	60 0.17-10.64 3.95
B	93		90 <0.001-0.47	89 <0.001-7.50	90 0.0057-12.00	93 1-100 26	34 21-273 100	33 15-90 35	33 1-183 68	9 0.13-9.61 5.76
C	74		46 <0.001-5.00	74 0.0019-78.00	20 0.008->78.00	74 0.5-99 50	38 29-152 89	38 17-82 41	38 9-98 48	10 0.32-9.74 4.53
D	34		34 <0.001-0.46	34 0.007-1.10	34 0.031-7.00	34 0.5-99 46	18 21-161 72	18 19-69 34	18 2-92 38	34 0.09-13.45 3.67
E	110		109 <0.001-0.45	110 0.0053-2.70	110 0.027-10.30	110 0.0-99 27	33 28-99 55	33 17-43 25	33 5-57 30	10 0.28-6.53 2.77
Nation	400		360 <0.001-5.00	396 <0.001-78.00	397 0.0057->78.00	400 0-100 40	189 21-273 88	187 15-90 35	187 1-183 55	123 0.09-13.45 3.95

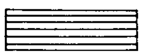
Note: For the purpose of this table, silts plot below the A-line and clays plot above the A-line on a plasticity chart.

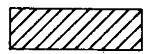
* Conclusions drawn on basis of data shown apply only to samples tested for this study. Data entries for each region are shown in the following format:

xx	Number of samples
xx-xx	Range of values
xx	Average value, if meaningful

** Legend for material types is as follows:

 Sand and gravel (>50% retained on #200 sieve).

 Silt (low plasticity fines).

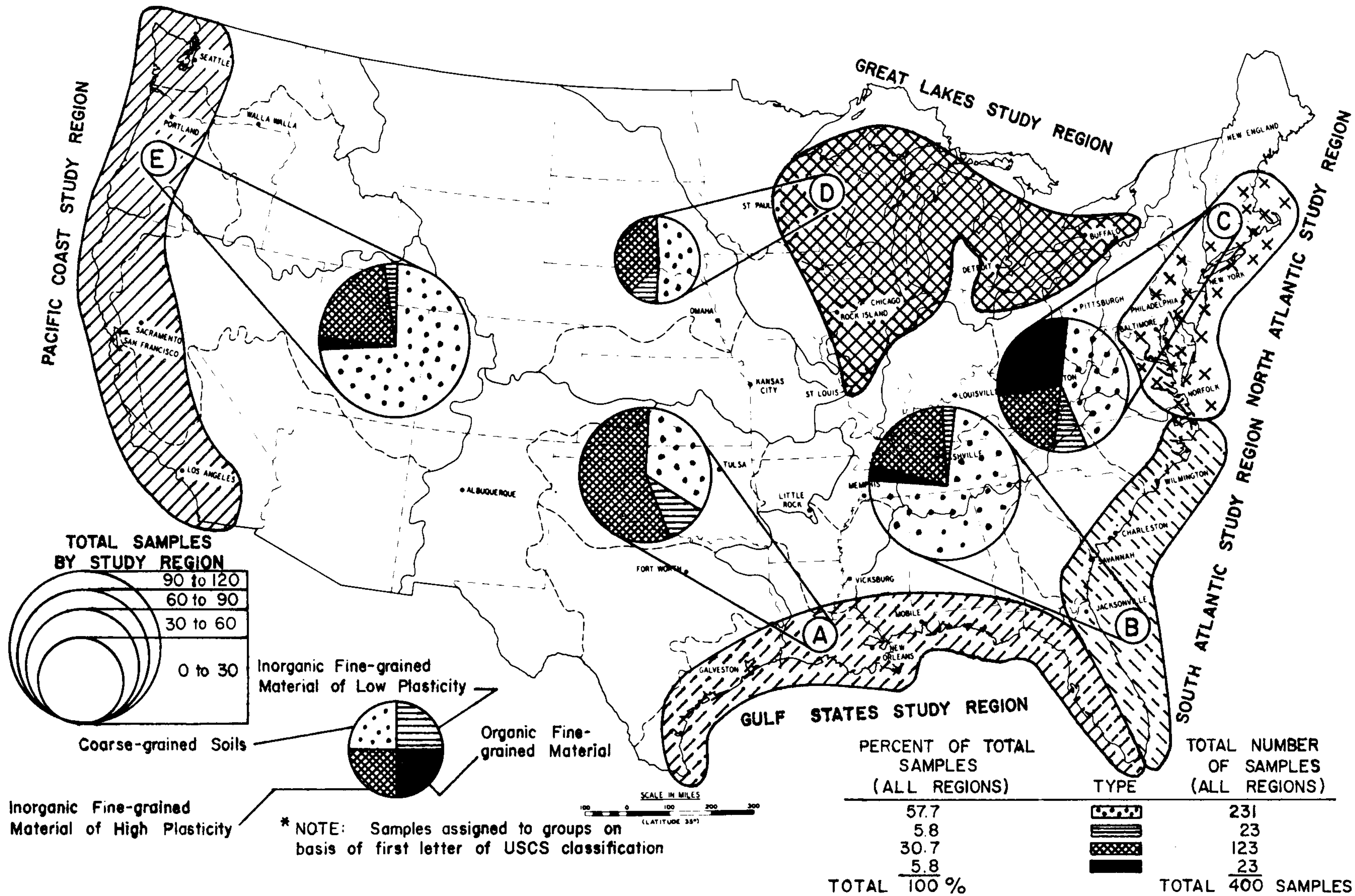
 Clay (high plasticity fines).

 Organic material (soil with organic matter present)

† D_{10} = Grain size at 10% passing.

D_{60} = Grain size at 60% passing.

D_{90} = Grain size at 90% passing.



PERCENT OF TOTAL SAMPLES (ALL REGIONS)	TYPE	TOTAL NUMBER OF SAMPLES (ALL REGIONS)
57.7		231
5.8		23
30.7		123
5.8		23
TOTAL 100 %		TOTAL 400 SAMPLES

Figure 1. Types* of dredged material samples, by region (from Bartos[6])

in the bars can be used to represent different types of dredged material, and the size of the bar can represent the quantity to be dredged. Plan and profile maps should be prepared for past dredging and used to show the future expected dredging requirements. Projections can be made from these maps to estimate the quantities required for future dredging activities.

Properties of dredged material in confined disposal areas

29. DMRP work unit 5A03[7] was an investigation of the applicability of conventional techniques for densifying dredged material. For that study some knowledge of the properties of dredged material in disposal areas, where densification would be implemented, was required. Most of the following discussion is taken from that report, which contains more detailed information as well as references to source material.

30. Physical properties. When pumped into a disposal area, dredge slurry can have a dry solids content ranging from near 0 to approximately 40 percent by weight. Generally, this value is about 13 percent. As the slurry flows across the disposal area, the solid particles settle from suspension: coarse particles near the inlet (dredge pipe), fine particles further into the area, and finest materials in the immediate vicinity of the outlet. As the disposal operation progresses, additional coarse-grained dredged material may accumulate in a mound near the inlet, displacing the soft fine-grained dredged material.

31. After the disposal operation is terminated, the surface water is drained from the disposal area. A surface crust begins to form on the fine-grained dredged material as it desiccates. With time, surface and base drainage cause some lowering of the groundwater table; the surface crust continues to increase in thickness; secondary compression effects develop; and consolidation occurs as the effective weight of the dredged material above the groundwater level is increased from a submerged weight to a saturated weight. The dredged material below the surface crust remains very soft and weak.

32. Data show that the water content of fine-grained dredged material in disposal areas is generally less than 1.5 times the liquid

limit of the material, and it is possible that in freshwater areas the water content is about equal to the liquid limit. The liquid limit of dredged material is generally less than 200, with most values between 50 and 100.

33. Engineering properties. The surface crust associated with fine-grained dredged material usually has a very low water content (often near the shrinkage limit) that increases slightly with increasing depth of the crust. The crust is usually overconsolidated due to the increase in effective stress caused by high negative pore pressures resulting from evaporation. Below the surface crust, however, the fine-grained dredged material is extremely soft and weak, with water content usually showing little change from the time of deposition (1.0 to 1.5 times the liquid limit). Density and shear strength increase very slightly, if at all, with increasing depth.

34. Data show that engineering properties (strength, compressibility, etc.) are generally better near the inlet than the outlet because the coarse-grained material settles near the dredge discharge. The engineering properties of the fine-grained material in the containment area near the outlet are poorer and improve very slowly with time.[6,7] In general, it has been found that dredged material is a soil at a high water content and if dewatered it exhibits properties expected of soil with a high potential for productive uses.[6]

Potential Uses

35. A major consideration during the planning phase of developing the reusable disposal area is the use of materials necessary to permit reuse of the containment area. If the dredged material solids being dredged could be matched with productive uses requiring all of these solids, the site would theoretically have an infinite service life. Seeking out productive uses will be a major responsibility of the planner. The planner must be aware of the needs for soils within the project areas. The fact that dewatered dredged material is a soil, may be analyzed as a soil, and can be used as a soil encourages the productive

use of dredged material as a natural resource.[6]

36. Based on research by the DMRP the following areas are promising for productive use of dredged material.

a. Landfill and construction material.

b. Surface mine reclamation.

c. Sanitary landfill.

d. Agricultural land enhancement.

37. For further guidance on promising productive uses of dredged material the reader is directed to Reference 1, which summarizes land enhancement research conducted under the Productive Uses Project (PUP) of the DMRP. It presents guidelines to engineers and planners for planning and implementing land improvement projects involving the use of dredged material.

Landfill and construction material

38. A need for landfill and construction materials exists in the coastal regions of the United States.[8] However, the need for these materials decreases with increasing distance inland. To be competitive with the other sources of material, dredged material must be economically and readily available. In addition, problems associated with the quality of the material, whether these problems are real or imaginary, must be resolved. A key to finding workable solutions to the disposition associated with dredging material and locating environmental and/or economic uses lies with local and regional planning agencies.[8] One of the first steps in promoting the removal of dredged material from disposal areas for use as landfill or construction is close coordination with planning agencies.

39. As a landfill material, dredged material should be competitive with other sources, but more ingenious disposal operations must be designed to eliminate problems that presently exist. The major problems cited by the agencies contacted during DMRP research[8] were the contamination and extremely high water content of fine-grained dredged material. Economic dewatering and solids treatment are considered essential to the productive use of large amounts of dredged material.

40. In addition to improvements in the quality of dredged material, improvements are required in disposal operations to make the dredged material more readily available to potential users. One suggestion made repeatedly during DMRP research was to stockpile processed (dewatered, decontaminated, etc.) dredged material in locations convenient to potential users. Such an operation must be carefully conducted to be dependable over a long period of time since it appears that, in general, sand and gravel operators (and possibly other potential users) will not avail themselves of dredged material resources until at least a 10-year supply of material is guaranteed.[8]

Surface mine reclamation

41. In many locations, strip mine reclamation using dredged material appears feasible.[8] Guidance for surface mine reclamation is given in Reference 1 which also includes a discussion on a surface mine reclamation demonstration project performed under the DMRP. Dewatered dredged material was hauled by truck from a containment area in the Chicago District and used to cover mine spoil at an abandoned mine.

Sanitary landfill

42. Another frequently mentioned potential use for dredged material is to cover compacted refuse in sanitary landfills. Under the DMRP, an investigation was conducted to evaluate the feasibility of using dredged material in solid waste management projects.[9] The conclusion was that dewatered, fine-grained dredged material would be suitable for use as an impermeable liner and as cover material at sanitary landfills. Coarse-grained dredged material would be suitable for constructing leachate collection drains and decomposition gas vents. Uses for fine-grained dredged material that had not been dewatered are extremely limited and are not likely to have a significant effect on disposal area reuse. Corps' Districts should cooperate with local and regional solid waste management authorities by making stockpiles of dredged material available at the reusable disposal site. Detailed guidance for evaluating and developing concepts for use of dredged material in sanitary landfill projects is provided in Reference 1.

Agricultural land enhancement

43. Dredged material can also be used to improve marginal lands for agricultural purposes.[10] Many marginal soils can be amended for increased crop production through mixing with a suitable dredged material. The physical and chemical characteristics of a marginal soil can be altered by mixing in a suitable dredged material to such an extent that water and nutrients become more available for crop growth. Increasing the elevation of marginal agricultural land with a cover of dredged material may improve surface drainage, reduce flooding, and lengthen the growing season.

Guidance for productive uses approach

44. The first step in planning for productive uses of dredged material from the proposed reusable site is to conduct a survey to identify potential markets or users. However, the planner must be careful in this step of planning. Because of legal complexities regarding dredged material ownership, State royalties, etc., Wakeford and Macdonald[3] should be reviewed, and legal and/or real estate experts should investigate Federal, State, and local laws that might pertain. Wakeford and Macdonald concluded that "material disposed of to other than governmental tax-supported or nonprofit organizations, e.g., a commercial enterprise, must be sold at its fair market value."[3] The following are considerations leading to the sale of dredged material:

a. If the District attempts to deal directly with consumers (such as persons needing landfill), this places the District in direct competition with commercial suppliers of raw materials. If the District allows its price to float (via competitive bids) in order to unload a large quantity of dredged material at a "fair market price," this will tend to take business away from commercial suppliers of similar materials and perhaps force them to cut prices to recover sales volume. Clearly, there would be strong opposition from commercial suppliers to such a District policy. Alternatively, the District could set prices that do not undercut those charged by commercial suppliers. (Note that Wakeford and Macdonald[3] cite many instances of sales and donations, apparently without serious opposition from commercial suppliers.)

b. The District could avoid the competition issue by dealing with commercial suppliers via competitive bidding, with the commercial suppliers then retailing the dredged material products to consumers. It is possible, however, that the bids received will not entirely cover the District's costs for processing and transporting the material. This would give an appearance of subsidization, which conflicts with past Corps policy wherein added costs for disposing of dredged material for the benefit of some individual must be covered by the beneficiary. This official policy, however, has been abrogated in recent years. Many Districts are incurring added costs to prevent alleged environmental degradation with the "beneficiary" being the American people. In a specific case, the St. Paul District is absorbing additional transport costs to remove dredged material from the environmentally sensitive floodplain and make it available for productive uses. Beneficiaries include local governments, e.g., the City of Minneapolis, Minnesota, and a commercial firm.* The DMRP legal constraints report suggests that the subsidy issue might be side-stepped if the Corps would "place the material on state-owned or controlled sites....and encourage the states to let competitive or negotiated contracts to reclaim the material, even if they (the States) have to subsidize the contractor."[3]

45. The market/user survey performed during the planning phase of reusable site development must include the following information:

a. Identify potential customers for dredged material products (both raw material suppliers and/or actual consumers). Adverse locations of customers (because of distance or relative inaccessibility from possible disposal areas) could preclude productive use of the dredged material and, therefore, affect the types of processing at the reusable site. Customer location can also influence reusable site location. For example, it would generally be advantageous from a transportation standpoint to locate a reusable site on the same side of the river as a potential major customer.

b. Quantify the potential demand. If the survey shows a substantial demand for products requiring extra processing (e.g., ASTM** Fine Aggregates), but little demand for unclassified material, then the District must weigh the advantages of reducing the waste disposal problem by the

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* Personal communication between Dennis Cin, U. S. Army Engineer District, St. Paul, Construction-Operations Division, and Thomas Raster, Acres American Incorporated, 8 Oct 1976.

** ASTM = American Society for Testing and Materials.

amount of dredged material that could be consumed versus the added costs for the equipment and multistage handling needed for the processing. To assist in this decision, the survey should assess revenue possibilities.

c. Determine possible revenue. If revenues from the sale of a specific product can offset the added cost for the extra processing, site design should include the necessary equipment. Even if the added cost is not entirely offset, sufficient savings might accrue from reduced waste disposal costs to justify the extra processing.

Refer to Reference 5 for more information regarding market and user surveys for dredged material.

Dredged Material Transport

46. If users do not come to the reusable site and remove the dredged material, it must be either stockpiled and moved later or transported inland for disposal and/or productive uses. A study of dredged material transport systems for inland disposal and/or productive uses was conducted.[11] This study serves as the basis for the following discussions.

47. It is important that transport systems and costs be evaluated during the feasibility stage of the reusable site planning process because transport costs are significant in determining project feasibility. Legal, political, sociological, environmental, physical, technical, and economical aspects should be examined in relation to availability of transport routes. Project feasibility is ultimately determined by estimating costs and selecting a specific transport mode.

48. Federal and State regulations and local ordinances control transport procedures which can impact on project viability. Problems to be considered include: allowable noise levels along transport routes (Noise Control Act of 1972), air pollution emission levels (Clean Air Act of 1970), traffic and shipment regulations in specific zones, truck weight limits (Highway and Safety Regulations), and accidental spill responsibility. Other considerations which are transport mode specific are presented in References 1 and 12, where specific transport systems and limitations are discussed.

Dredged material
transport systems and modes

49. Transport systems. The major elements to transport systems are loading, transporting, and unloading. The loading and unloading operations are situation dependent and are major cost items for short distance transport. The hydraulic pipeline is the only system which requires a unique rehandling operation; all other modes may interchange loading and unloading components to suit the specific needs. Loading, unloading, and transporting elements can be separated into detailed components and each component examined for capacity, operational schedule and cycle, and costs of equipment and operation and maintenance.

50. Restrictive considerations are enumerated after each transport mode to ensure that unforseen problems do not arise subsequent to the selection of that transport mode for a specific project. The considerations should delineate viability of any particular transport mode.

51. Transport modes. The planner should consider both land and water modes. Five transport modes, hydraulic pipeline, rail haul, barge haul, truck haul, and belt conveyor, were investigated by the DMRP.[11] They concluded that when unusual circumstances exist for a given transport need, the following practical distance limits are recommended for each transportation mode:

a. Hydraulic pipeline. Recommended for distances up to 125 miles.*

b. Rail haul. Recommended for distances between 50 and 300 miles.

c. Barge haul. Recommended for all transport distances where suitable waterways exist.

d. Truck haul. Recommended for distances up to 50 miles.

e. Belt conveyor. Belt conveyor movement should be considered for those applications where large volumes are required to be moved short distances.

52. It is recommended that the planner follow this sequence when selecting the most desirable transportation alternative:

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* A table of factors for converting U. S. customary units of measurement to metric (SI) can be found on page 7.

a. Identify the available transportation routes and their respective distances for the movement of dredged material to an inland disposal site.

b. Determine the nature and characteristics of the dredged material transported, i.e., slurry or dried state.

c. Determine the annual volume of dredged material to be transported and volumes anticipated annually.

d. Estimate costs for each mode of transportation. Use Reference 11 and other sources for cost estimates.

e. Evaluate technical, legal, environmental, and institutional considerations for each mode to ensure the practicability of the application.

f. Select the desired transportation alternative.

53. It is possible for specific applications that barge and truck haul, or barge and pipeline slurry modes, as well as other potential combinations, could be utilized. Unit costs can be combined to evaluate the total transportation systems cost. Table 2 is presented to provide a comparison of costs for the five modes of transport discussed above. Detailed cost evaluations for these modes of transport are given in Reference 11. Table 2 and Reference 11 provide general cost guidance for these transportation modes. Since these costs are highly site specific, costs should be developed specifically for each reuse site considered.

General planning guidance

54. Dredged material transport will always be required at the disposal area reuse site. It may simply be needed to stockpile the resource material at the site to provide easy access for users. The significant cost for dredged material transport would be associated with inland transport of the material. On the basis of DMRP research, the following general guidance is provided for the planner:

a. Truck haul is the most convenient and easily operated mode of transportation available and is recommended for short distances.

b. Rail haul and barge movement of dredged material are feasible over a wide range and are the only viable modes of transport for distances beyond 125 miles.

Table 2

Comparison Costs in Dollars per Cubic Yard at Various Transport Systems, Quantities, and Distances

Annual Quantity cu yd	Transport Distance miles	System				
		Pipeline	Rail	Barge	Belt	Truck
500,000	10	2.47	*	2.47	8.98	4.57
	20	3.14	*	3.14	15.15	6.61
	100	9.54	7.18	4.71	*	13.69
	250	*	9.32	7.41	*	*
1,000,000	10	1.46	*	2.92	5.39	3.73
	20	1.91	*	3.14	13.47	4.19
	100	6.45	5.39	4.49	*	12.91
	250	*	7.58	7.18	*	*
3,000,000	10	0.79	*	2.70	2.25	3.17
	20	1.12	*	2.92	3.93	3.56
	100	4.10	4.21	4.49	*	12.35
	250	*	5.34	7.35	*	*
5,000,000	10	0.67	*	2.81	1.68	3.05
	20	0.90	*	2.92	3.14	3.42
	100	3.48	4.04	4.38	13.58	12.07
	250	*	6.06	7.07	*	*

Note: The general cost estimates in this table are taken from References 12 and 13. These costs are adjusted to March 1978 dollars. (Table taken from Reference 1.)

* Indicates economically not feasible.

c. Constraints to barge and rail hauls are route availability and proximity to inland disposal site and/or productive uses sites.

d. Belt conveyors are the most expensive mode of transport, and have been used effectively for loading and unloading.[1]

e. Hydraulic pipeline is the only valid transport mode for dredged material slurry.

Site Selection for Reusable Site

Outline of methodology

55. The following methodology provides a step-by-step procedure for identifying the most economical site location. This methodology includes consideration of site design in the site selection process. Social and environmental constraints are factored into the selection process; impacts must be weighed in choosing among alternatives that are economically similar. For more details on site selection, the reader should refer to Reference 5, on which this section was based. The methodology is broken down into phases as follows:

a. Phase I - Preliminary Data Collection:

(1) Define dredging program to be served--dredging locations, quantities, primary dredge, and dredge-to-disposal site transport system.

(2) Determine critical dredged material properties, such as physical and engineering characteristics, settling properties, contaminants, etc.

(3) Locate viable markets/users and examine capabilities of regional transport system.

(4) Identify possible disposal sites--existing disposal sites or other undeveloped areas. Consider institutional and dredge/initial transport capability constraints.

b. Phase II - Selection of Candidate Disposal Site/Systems:

(1) Select viable candidate disposal sites--locations and types (conventional, reusable, or waste). Use clear-cut and judgmental constraints to combine individual disposal sites into alternative multi-site systems capable of handling the projected dredged material quantity to screen out unsuitable

sites. Consider dredge/initial transport capabilities, area/volume needs, market/user requirements, availability of offsite transport, etc. Then use qualitative assessments of relative costs and social/environmental impacts to eliminate suitable, but less desirable, sites.

(2) Conduct necessary field studies at remaining candidate sites to collect site-specific data on: geology, groundwater, possible borrow areas, social/environmental setting, applicable effluent standards and ambient water quality, and land costs. For reusable sites, also collect information on specific market/user needs, availability of waste disposal areas, and offsite dredged material transport.

c. Phase III - Process Selection/Preliminary Site Design:

(1) Select the specific reusable process best suited for each candidate.

(2) Develop preliminary layouts and cost estimates using generalized design and cost guidelines provided in References 5 and 11 and in Parts II and IV. Determine total costs and impacts of alternative systems.

(3) Identify impractical, costly, and socially/environmentally unsatisfactory sites.

d. Phase IV - Candidate Screening:

(1) Select best disposal systems (no more than two or three). Economics is the primary consideration at this point, social/environmental impacts are used to choose between economically similar alternatives.

(2) Collect detailed site data--topography, foundation soils, groundwater, environment, unit costs. Conduct public information program; survey public reaction to probable impacts.

e. Phase V - Detailed Designs and Cost Estimates:

(1) Adjust processes and layouts to fit additional engineering and social/environmental information.

(2) Prepare proper engineering designs and cost estimates to replace those prepared in Phase III from generalized design and cost guidelines.

f. Phase VI - Final Selection. Make final selection of disposal area reuse site locations/processes on economic basis, with full consideration of unavoidable adverse social/environmental impacts.

56. The methodology is structured so that it may be entered or left at any stage, provided the planner has the necessary inputs or outputs. For example, a planner's experience might narrow the list of possible candidates to a few. This planner could enter the methodology at Phase III or even Phase V if the specific disposal operation has already been selected. Conversely, a District concerned merely with the feasibility of changing its present dredged material disposal program might start at Phase I and exit after Phase IV when preliminary costs and operation modes of alternative sites have been determined.

Input requirements

57. The sponsor plays a vital role in the methodology beyond that of just providing obvious inputs, such as field data on candidate sites, dredge plant, dredged material, etc. The methodology relies on sponsor experience and judgment at several key decisionmaking points. This is particularly evident early in the methodology during initial selection of the number, location, and operational mode (conventional or reusable) of the candidates. Without this early decisionmaking, the methodology would become impossibly cumbersome; detailed analyses would have to be made for all possible alternative disposal operations at all likely sites, an impracticably costly and time-consuming task.

58. In Phase I, for example, the sponsor must identify possible disposal sites and, for reusable disposal sites, likely markets/users and potential waste disposal sites. In some cases, the decision will be straightforward. A candidate area with poor landward access likely will not be suitable for a reusable site requiring offsite transport of products and wastes. However, this same candidate might serve satisfactorily for a conventional site where the material need not be removed. The methodology provides guidelines to assist in these decisions, but experience and judgment still play a major role. Obviously, a more efficient study can be conducted if the study area is well known. Sponsor personnel can focus on a small number of better candidates, rather than cover a large number of candidates with varying potential.

59. In Phase III, the sponsor selects specific operations for each candidate site. These decisions are made on the basis of a market

analysis and a review of planned land use developments, anticipated legislative trends (particularly in the environmental field), projected dredging quantities, etc. However, these decisions still amount to subjective assessments because the above factors can change quickly.

60. The most important subjective judgments are made in Phases I-III. Later in the methodology, decisions become more objective as the number of alternatives decreases. The fewer alternatives permit more extensive analysis, hence more quantitative measures of economic, social, and environmental factors. Clearly, however, the sponsor's decisionmaking power is never usurped by the methodology; the methodology merely provides the sponsor with a tool laying out all the pertinent factors in a logical, step-by-step manner.

61. The sponsor should approach the methodology with the attitude that the results of this study, if adopted, will be the major influence on the dredging program over the next 10, 20, or more years. Accordingly, the sponsor should be prepared to make a serious commitment in terms of manpower, time, and money.* Savings will result if records of the District's dredging program are complete, accurate, and up-to-date and if District personnel are familiar with the study area.

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* A purely conceptual study or a study involving only one or two dredging locations will be smaller in scope, thereby reducing the magnitude of the study considerably.